JSR Corporation

EUV Resist Development Status toward sub-20nm Half-Pitch

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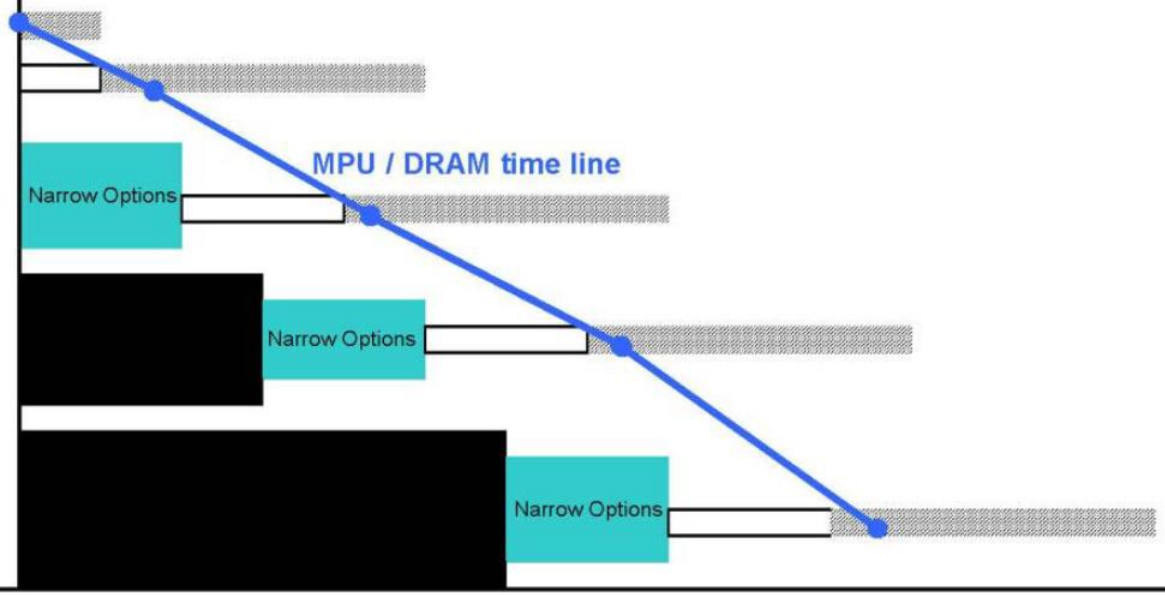
Lithography Road Map

	First Year of IC Production	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	DRAM ½ pitch (nm) (contacted)	36	32	28	25	23	20.0	17.9	15.9	14.2	12.6	11.3	10.0	8.9	8.0	7.1	6.3
	MPU/ASIC Metal 1 1/2 pitch (nm)	38	32	27	24	21	18.9	16.9	15.0	13.4	11.9	10.6	9.5	8.4	7.5	7.5	7.5
45	193nm Imm																
32	193 nm DP																
22	EUV 193nm MP ML2 (MPU) Imprint (DRAM)																
16	EUV 193nm MP ML2 Imprint DSA + litho platform																
11	EUV / EUV + MP EUV (6.Xnm) ML2 Imprint Litho + DSA Innovation																



http://www.itrs.net/Links/2011ITRS/2011Chapters/2011Lithography.pdf

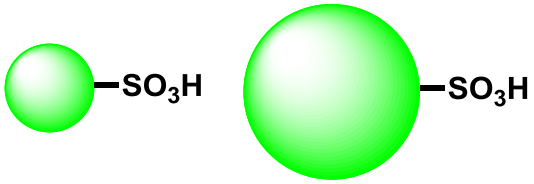
- ✓ ***EUVL is leading candidate for next generation lithography***
- ✓ ***In this study, JSR reports material development status for sub-20nm half-pitch.***

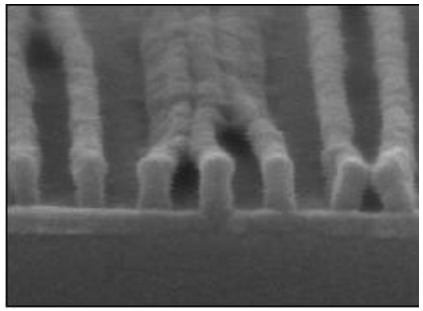
Strategy for sub-20nm hp Generation

Resolution improvement is significant challenge for sub-20nm hp generation

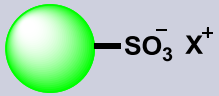
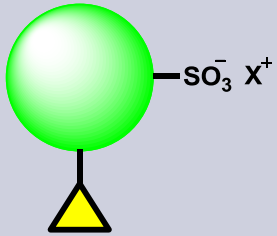
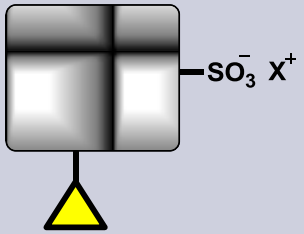
- ***✓Acid diffusion control***
  - ***Development of PAG with short acid diffusion length***
- ***✓Suppression of pattern collapse***
  - ***Development of under layer***
  - ***Optimization of development process***

Acid Size





Short Acid Diffusion Length PAG

	PAG-1	PAG-2	PAG-3
PAG structure			
Van del Waals (VDW) vol. (relative value) of anion	100	170	190
Functional group of anion	None	Polar unit	Polar unit
PAG backbone	Flexible	Flexible	Rigid
Acid diffusion length* (relative value)	100	41	14

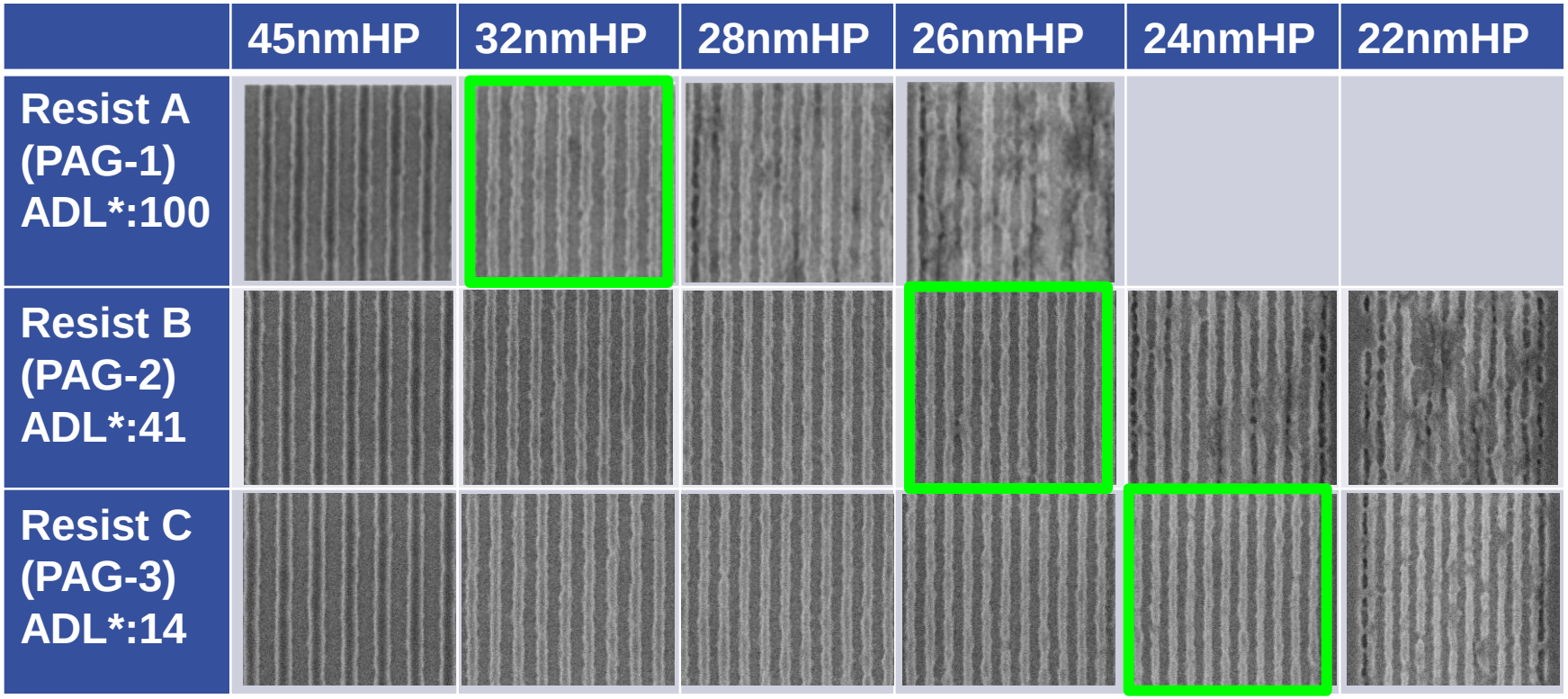
: Rigid unit : Flexible unit : Polar unit X^+ : Onium salt unit

Jae Hyun Kim et al, Proc. SPIE 5376, 790 (2004).

Jae Hyun Kim et al. J. Photopolym. Sci. Tech. 17, 379 (2004).

✓ ***PAG acid diffusion length was controlled by unique PAG anion design***

Short Acid Diffusion Length PAG -Ultimate Resolution-



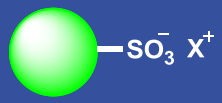
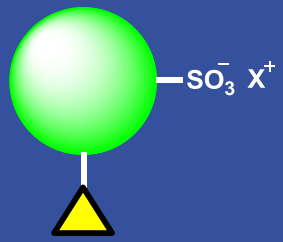
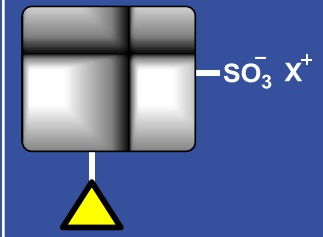
*ADL: Acid diffusion length (relative value)

Sub. Si, Thickness: 50nm, Exp. SFET. NA 0.30

Ref: Kouta Nishino, Ken Maruyama, Tooru Kimura, Proc. SPIE 7969-89 (2011)

- ✓ ***Resist with short acid diffusion length PAG showed high resolution***
- ✓ ***Good relationship between resolution and acid diffusion length was observed***

Short Acid Diffusion Length PAG -Lithography Performance-

	Resist A (PAG-1) ADL*:100	Resist B (PAG-2) ADL*:41	Resist C (PAG-3) ADL*:14
			
Resolution	32 nm HP	26 nm HP	24 nm HP
LWR (28 nm HP)	Not resolve	7.0 nm	5.9 nm
Sensitivity (28 nm HP)	11.0 mJ/cm2	13.0 mJ/cm2	15.1 mJ/cm2
Z-factor*	-	7.0E-08	5.7E-0.8

****Z-factor [(mJ*nm³) = (RES)³ * (LER)² * (SEN)] is used for quantitative resist comparison. Wallow, T. et al Proc. SPIE 6921, 69211F (2008).***

- ✓ ***Short acid diffusion length PAG is good for balanced resolution, LWR and sensitivity performance***

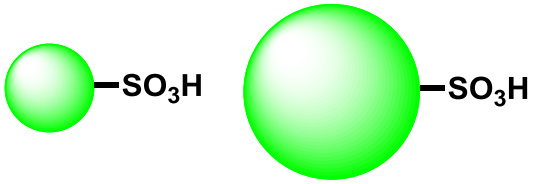
Strategy for sub-20nm hp Generation

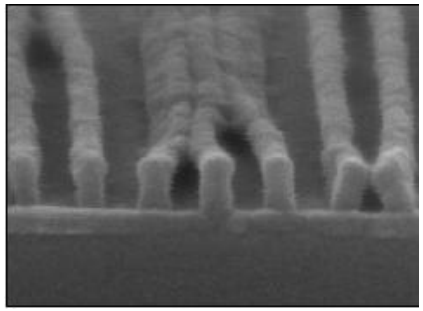
Resolution improvement is significant challenge for 16 nm HP generation

- ***✓Acid diffusion control***
  - ***Development of PAG with short acid diffusion length***

- ***✓Suppression of pattern collapse***
  - ***Development of under layer***
  - ***Optimization of development process***

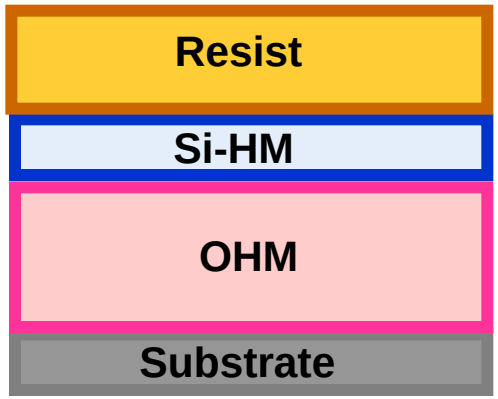
Acid Size

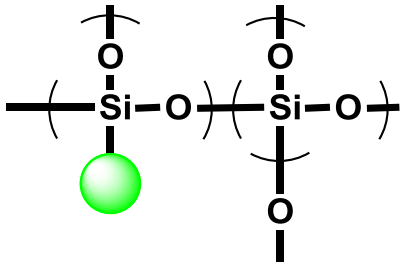




Development of Under Layer – Si-HM

Multi-layer system



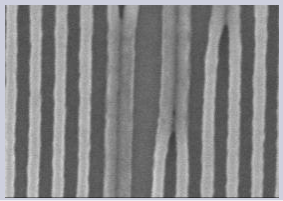
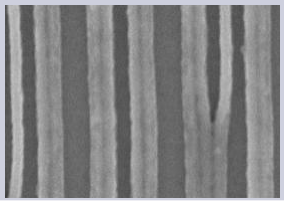
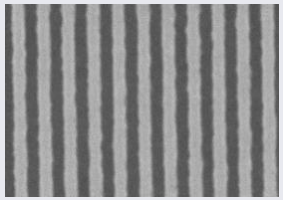
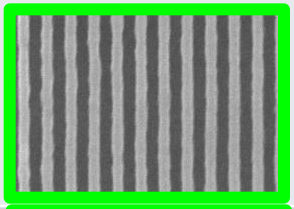
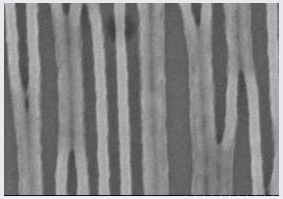
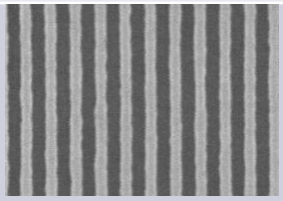
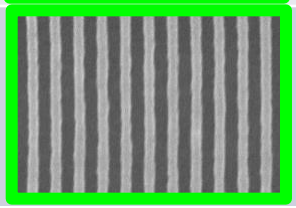
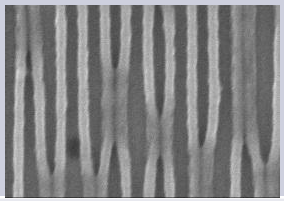
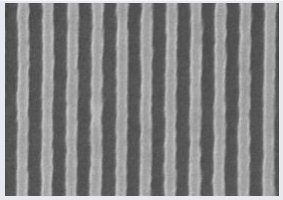
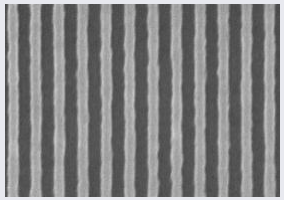
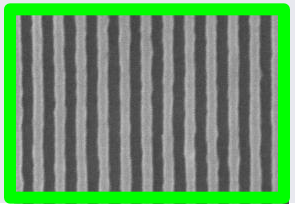


Multi layer system provides wider margin for resist pattern line collapse as well as etching process

	Si-HM-A	Si-HM-B	Si-HM-C	Si-HM-D
Contact angle (relative value)	100	104	106	109

✓ ***Si-HMs with different contact angle were evaluated to understand the effect of Si-HM on resist pattern line collapse***

Development of Under Layer – Si-HM -Ultimate Resolution-

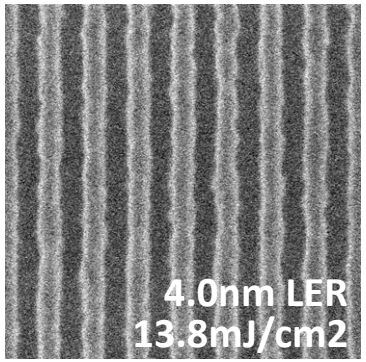
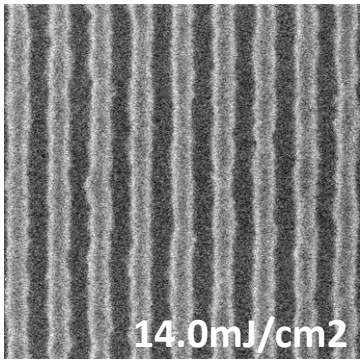
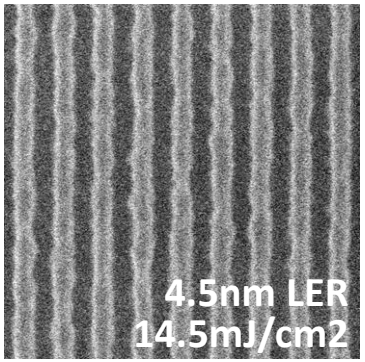
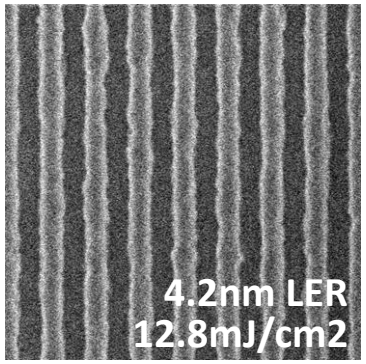
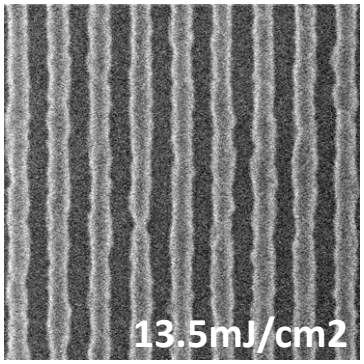
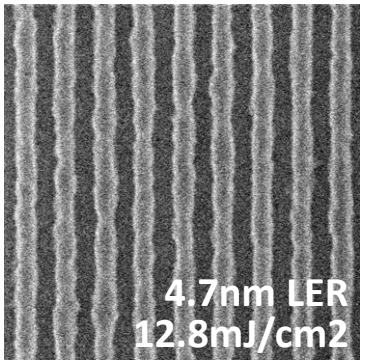
Si-HM	30 nm HP	28 nm HP	26 nm HP
Si-HM-A CA(relative value):100			
Si-HM-B CA(relative value):104			
Si-HM-C CA(relative value):106			
Si-HM-D CA(relative value):109			

Exp. NA 0.30, Dipole

- ✓ *High contact angle of Si-HM improves resist pattern collapse*
- ✓ *Contact angle is the key factor for improvement of pattern collapse*

JSR EUV Resist Performance on Si-HM - NXE3100 -

Resist - C1

	28nm LS	26nm LS	25nm LS
EUV resist / UL (50nm) / Silicon (20nm)			
EUV resist / Si-HM (50nm) / O-HM (30nm) / Silicon (100nm)			

*HMDS applied before resist coating

Exp. NA 0.25, Conventional

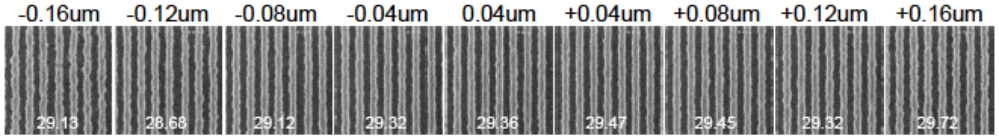
✓ ***JSR Si-HM showed good litho performance.***

JSR EUV Resist Performance on Si-HM - NXE3100 -

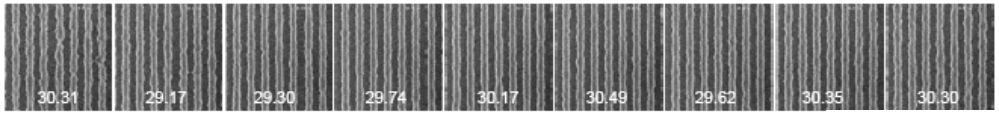
Resist - C1

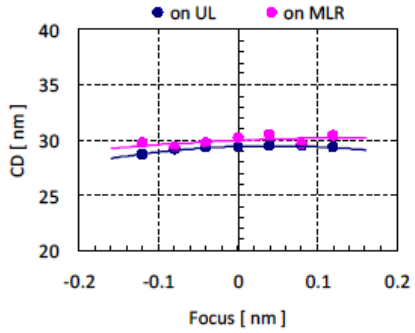
L30P60(L30) DOF

on UL, 13.5mJ



on MLR, 13mJ

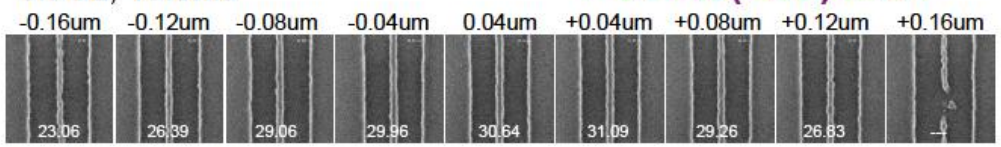




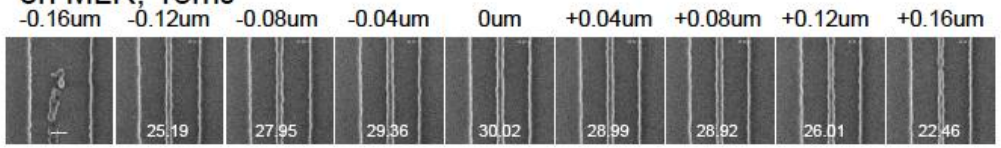
imec © IMEC 2011 / CONF

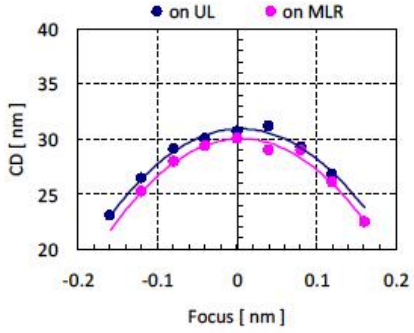
L30iso(L36) DOF

on UL, 13.5mJ



on MLR, 13mJ





- ✓ ***JSR Si-HM showed good resist collapse margin at both dens and iso line.***

Strategy for sub-20nm hp Generation

Resolution improvement is significant challenge for 16 nm HP generation

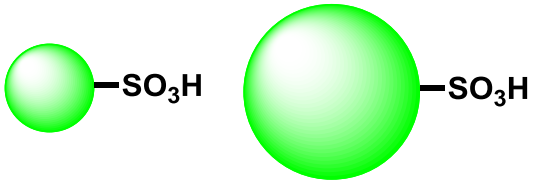
✓***Acid diffusion control***

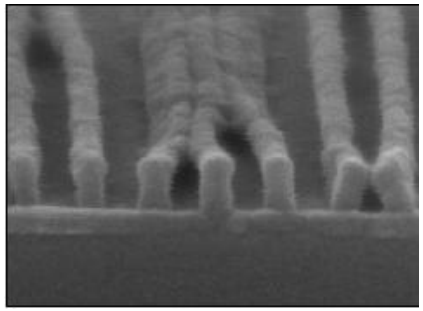
- ***Development of PAG with short acid diffusion length***

✓***Suppression of pattern collapse***

- ***Development of under layer***
- ***Optimization of development process***

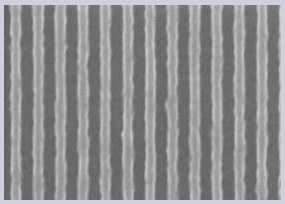
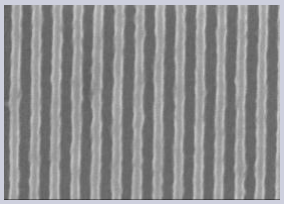
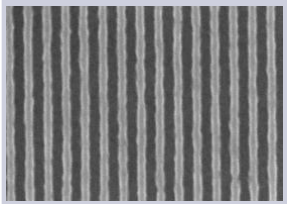
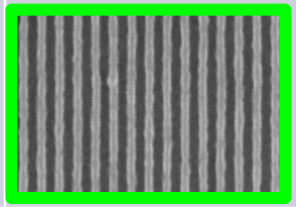
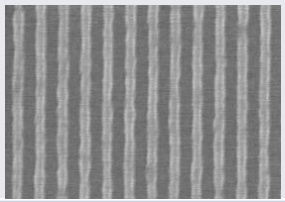
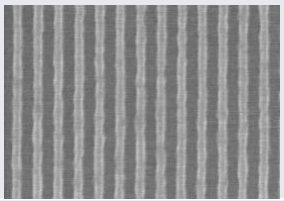
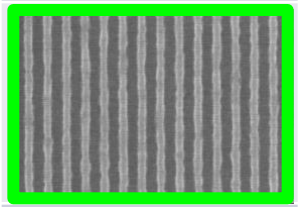
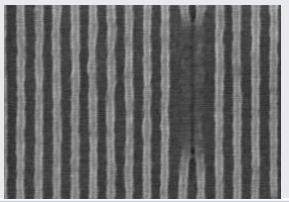
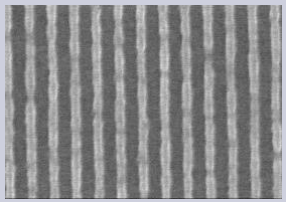
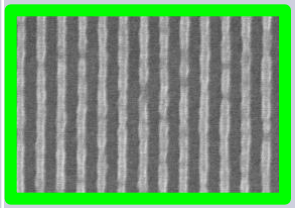
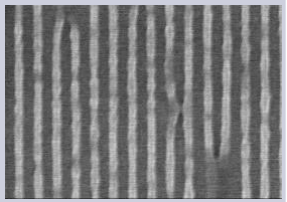
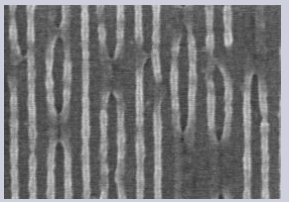
Acid Size





Effect of Development Time -Ultimate Resolution-

Resist - C1

Development time	26nmHP	24nmHP	22nmHP	20nmHP
Short				
Standard				
Long				

Exp. NA 0.30, 18 nm dipole

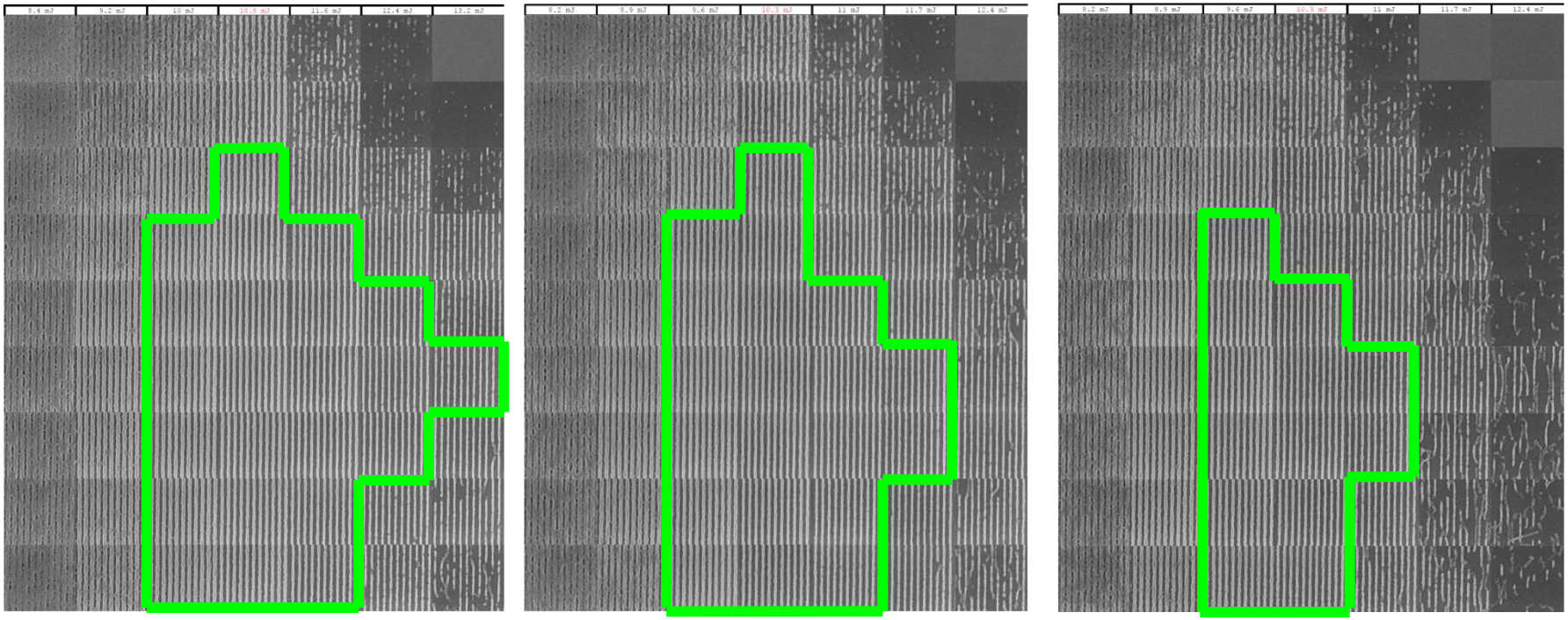
✓ ***Short development time improves resist resolution***

Effect of Development Time – Process Window

30 nm HP process window

Short Dev. time | Standard Dev. time | Long Dev. time

50nm Focus step



Exp. NA 0.30, Quadrapole

- ✓ ***Best process margin factors (PW and pattern collapse) observed at short development time***
- ✓ ***Development time is important factor to obtain large process window***

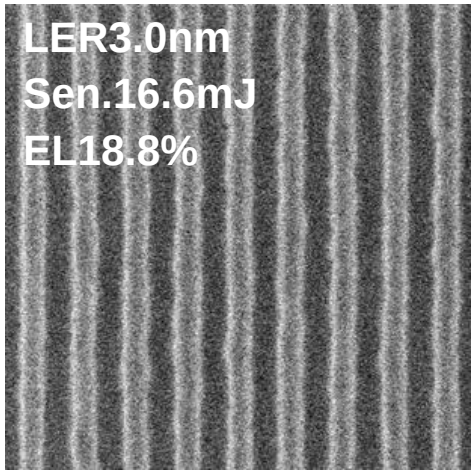
Recent Progress of JSR EUV Resist on imec's NXE:3100

Resist – C2

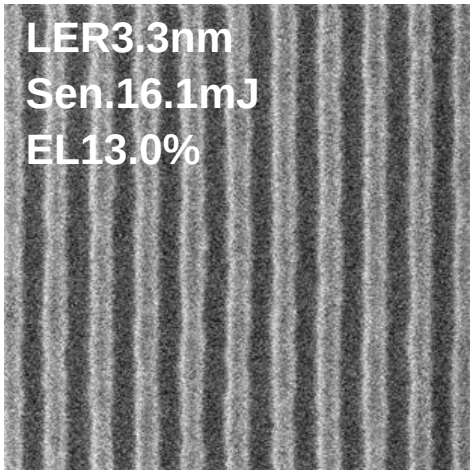
	JSR EUV resist w/FIRM* rinse	Target
Ultimate resolution	20nmHP	20nmHP
LER@22nmHP	3.3nm	3.0nm
Sensitivity @22nmHP	16.1mJ/cm^2	<15mJ/cm^2

*FIRM™ Extreme™ 10

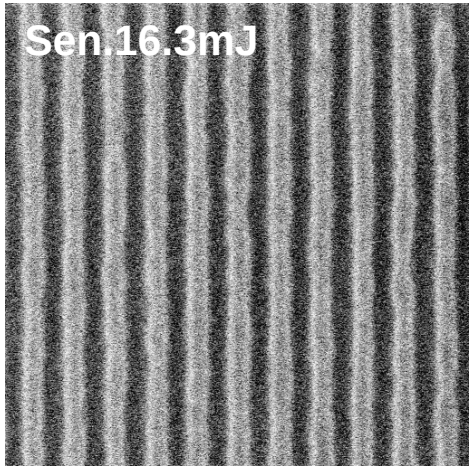
25nmHP



22nmHP



20nmHP



Exposure:NXE:3100 , NA0.25, Dipole60X, Courtesy of imec

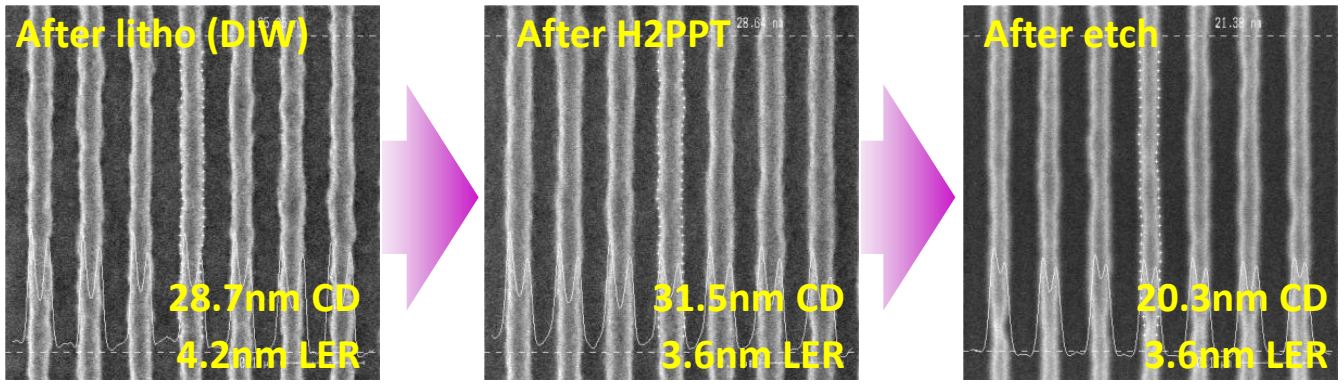
✓ ***JSR EUV resist shows good balanced RLS performance***

LER Mitigation by Process Optimization

Resist - C2

Etch based→

30nmLS w conventional

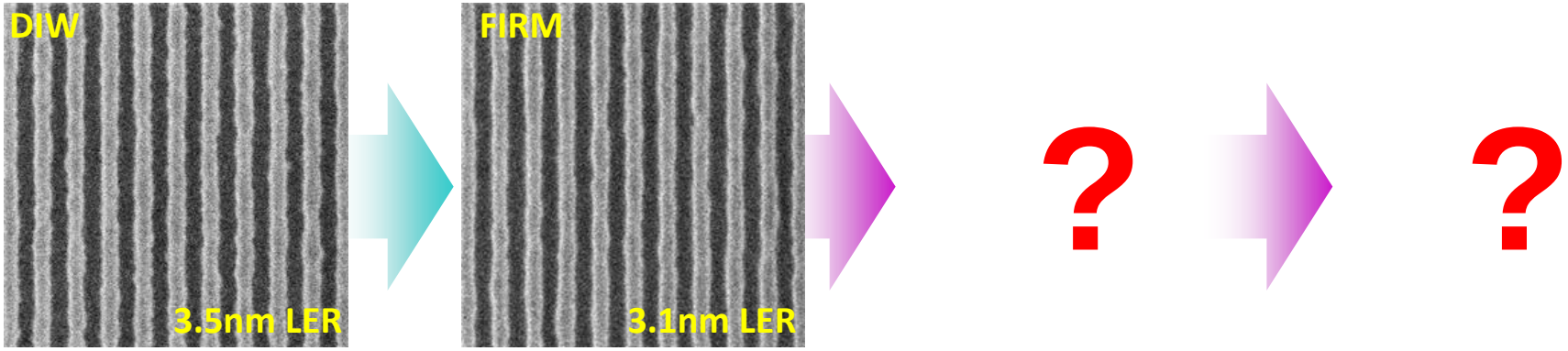


-12.3% LER

-0.1% LER

Track based↓

22LS w dipole



-11.4% LER

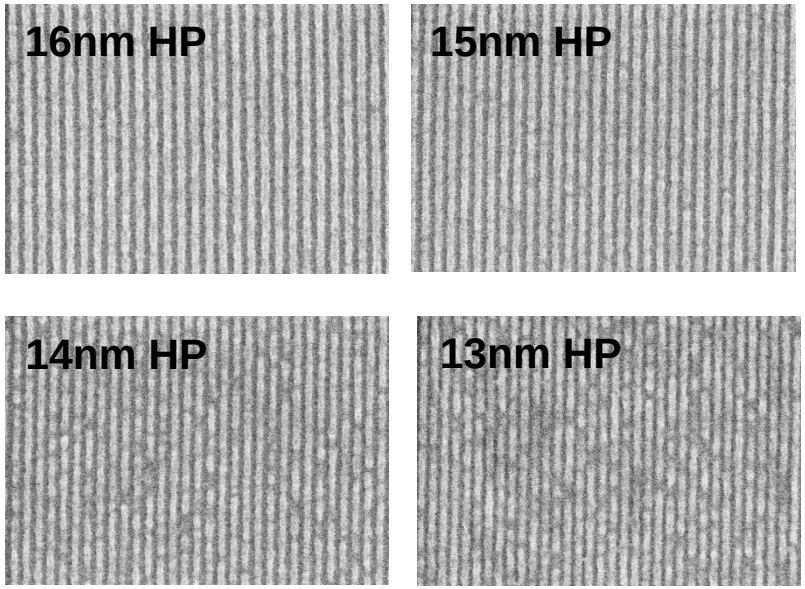
Courtesy of imec

✓ ***Innovative processes show potential to mitigate LER.***

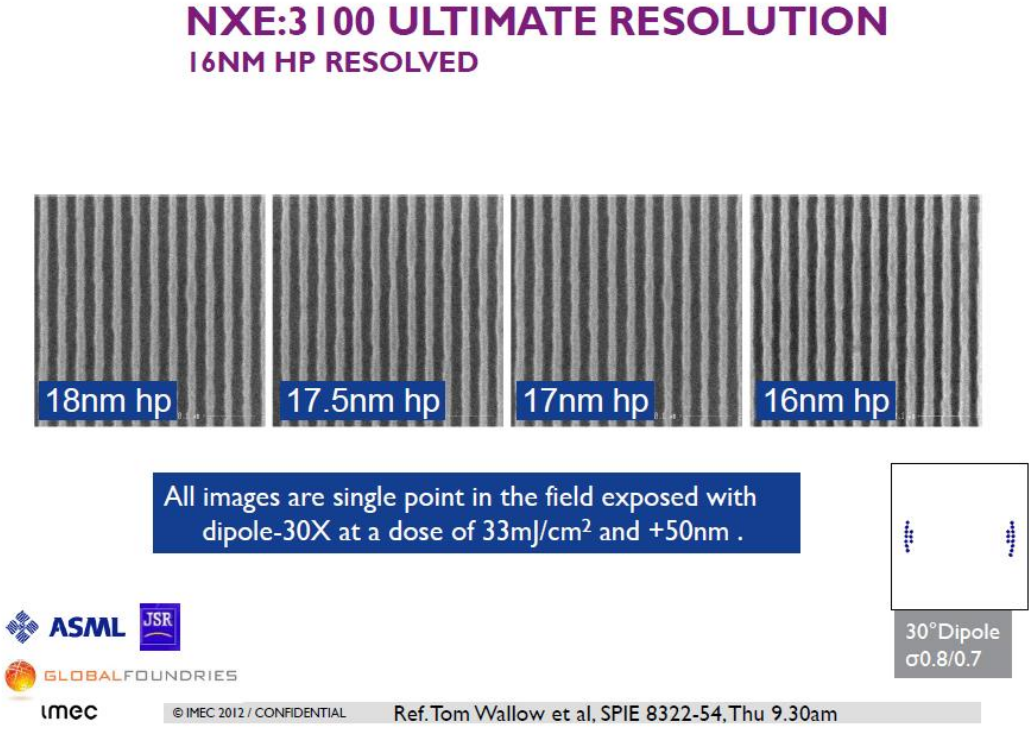
Resolution Challenging in EUV Lithography

Resist - C3

LBNL MET ultimate resolution



LBNL MET, NA0.3, Pseudo PSM
Dose: 44mJ/cm^2



Imec's NXE3100, NA0.25, Dipole30X
Dose: 33mJ/cm^2

- ***Resolution at 16nmhp and beyond was performed.***

Summary

- **Material Development**
  - **Uniquely designed PAG with short acid diffusion length was good at resolution improvement.**
- **Substrate and Process**
  - **Silicon based hard mask with high contact angle improved resist pattern collapse significantly.**
  - **Development process optimization improved resist line collapse margin as well as its roughness.**
- **Advanced EUV Resist Performance**
  - **Resist resolution at 16nmhp and beyond was performed, which encourages industries to apply EUV lithography for device manufacturing.**

Acknowledgment

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Thank you for your attention !!

Materials Innovation

JSR

With chemistry, we can.